ON-LINE MONITORING AND DYNAMIC MODELING OF WASTEWATER TREATMENT

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Abstract. Success in the development and application of a model requires, as a rule, high-quality field data. In general, studies in controlling the dynamics of wastewater treatment processes have been poorly served in their access to such data. The University of Georgia's Environmental Process Control Laboratory has been developed in order to rectify this limitation. Its purpose is to support the development of process models and, where appropriate, procedures of decision support and automatic control for these systems. Preliminary results from commissioning trials with the Laboratory at the Athens, Georgia, Water Pollution Control Facility No. 2 are reported. Results are presented for the simulation of nitrification and denitrification.

INTRODUCTION

Scarcity of on-line experimental data is one of the reasons that have long obstructed practical progress in modeling wastewater treatment systems (Beck, 1986), and in implementing efficient control actions (Lessard & Beck, 1991). The University of Georgia's recently commissioned Environmental Process Control Laboratory (EPCL), however, is transforming this situation. The purpose of this paper is to summarise progress in applying the EPCL for monitoring and control of wastewater treatment.

SITE DESCRIPTION

The Athens Water Pollution Control Facility No. 2 provides primary and secondary treatment to the sewage from the western residential area of Athens-Clarke County. Preliminary treatment stage involves the removal of gross solids through screens. During the biological treatment stage the concentration of carbon and nitrogen-based pollutants are reduced. Sludge produced by the aeration tanks settles to the bottom of the secondary clarifiers, where it is collected and then either returned to the aeration tanks to aid in the treatment process or thickened and digested in anaerobic digesters. Effluent of the secondary clarifiers is disinfected with chlorine, which thus completes the whole treatment process prior to discharge of the effluent to the Middle Oconee River.

There are two aeration tanks in the plant, each of which has three channels. The sewage flows in sequence from the outer channel through the middle channel into the inner one. Effluent from the two tanks is then combined and distributed equally to three secondary clarifiers.

ENVIRONMENTAL PROCESS CONTROL LABORATORY

The Environmental Process Control Laboratory (EPCL) can be used in many contexts, but especially in the study of municipal and industrial wastewater treatment and the protection of surface water quality. In this research the EPCL was deployed for the development of a dynamic process model for the activated sludge system at the Athens Water Pollution Control Facility No. 2 (Beck and Liu, 1998).

The EPCL comprises two mobile trailers. Each of the trailers is equipped with on-line automatic monitors. One houses a respirometer, ammonium-N monitor, total organic carbon (TOC) monitor, and turbidity sensor coupled with a homogenizer and debubbler. The other trailer has a respirometer, NOx (nitrite and nitrate) monitor and orthophosphate-P monitor. Other than the on-board monitors, out-board monitors such as two DO probes, a mixed liquor suspended solid (MLSS) probe, and a sludge blanket level sensor are available. Most of these monitors have the capability of self-cleaning and self-calibration.

Each of the trailers can continuously receive samples from three locations on site. All the samples are pretreated through ultrafilters to ensure they are solid-free prior to analysis. The filtrates are passed in sequence to each individual monitor using pneumatical valves.

In addition to the 15-minute-average data, the built-in data loggers can also log in detailed data with much shorter time intervals of down to one second. Since the data logger can only hold data for up to several days, the amassed on-line data are accordingly transferred from the local system to a remote UNIX based workstation through a phone line on a regular basis.

SAMPLING REGIME

The sampling campaign started on February 1, 1998 and finished on April 28, 1998. Given the potential for achieving desired effluent quality with just one of the two aeration tanks operating but saving significant cost, input crude sewage was fed exclusively to aeration tank No. 2 from 11 February, 1998, onwards. The entire sampling comprised of two sections. The first section (02/01/98~04/06/98) was a relatively comprehensive monitoring of the whole activated sludge system. While the second section (04/20/98~04/28/98) was centered around the secondary clarifier, with measurements of the aeration tank effluent, returned activated sludge immediately before its feed point to the aeration tank, and the secondary clarifier outflow. The first section was relatively more successful, since frequent blockage of the sampling pumps for the returned activated sludge (RAS) was encountered in the second section. Tables 1 and 2 summarise the observations made respectively during sections 1 and 2 of the campaign.

Table 1. Variables In The First Sampling Section

Locations	Variables
Crude Sewage	Flow,NH_4-N,TOC NOx,Ortho-P
Aeration Tank 2 Outer Channel	Respirometry, NH4-N, TOC
Aeration Tank 2 Middle Channel	Respirometry NOx,Ortho-P, DO
Aeration tank 2 Inner Channel	Respirometry NH_4-N, TOC DO, MLSS
Secondary Clarifier	Sludge Blanket Level
Secondary Clarifier Effluent	NOx,Ortho-P Turbidity

Table 2. Variables In The Second Sampling Section

Locations	Variables
Aeration Tank 2 Inner Channel Effluent	Respirometry,NH4-N, TOC,NO_x, Ortho-P, DO, MLSS
RAS At The Aeration Tank Inlet	Respirometry,NH4-N, TOC, NO_x, Ortho-P
Secondary Clarifier	Respirometry,NH4-N, TOC, DO, Turbidity SBL, NO_x, Ortho-P

SOME PRACTICAL EXPERIENCES WITH THE ON-LINE MONITORS

The on-line monitors require attentive service and maintenance if they are to function properly. For example, the ammonium-N concentration decreases fairly abruptly on February 12, 1998, as seen in Figure 1. This particular decrease is caused by the misplacement of the sodium hydroxide suction tube. Sodium hydroxide for the ammonium-N monitor is used to maintain a specific alkalinity. After recovering the normal NaOH transport into the monitor, the curve rises again. On some occasions the ammonium-N monitor failed due to the faulty ammonia probe, in which case the voltage output of the probe was extremely low compared to its optimum value. In order to overcome problems of this nature, the ammonia probe was replaced, and the monitor was recalibrated and left to stabilize for at least 24 hours until the normal measurement was resumed. Generally, after replacement and recalibration the voltage output would return to the optimum level.

USE OF ON-LINE MONITORS FOR PROCESS MONITORING AND CONTROL

So far there has been no discharge permit for orthophosphate-P. Thus the whole activated sludge process can in principle be monitored and manually controlled by measuring the ammonium-N concentration, nitrate-N concentration and DO concentration in the secondary clarifier effluent. The integration of the on-line monitors into the plant operation would introduce scope for improving overall plant performance. The on-line data could be used directly by the plant operators for process fault detection and advanced process control.

Process Fault Detection

The activated sludge process requires a thorough control of the dissolved oxygen concentrations in the aeration tanks. It is important to sustain a specified dissolved oxygen level for efficient nitrification and reasonable energy consumption. On February 19 the plant lowered the water level in the aeration tank No. 2. Storm runoff was expected with the risk of sludge washout. But the ammonium-N concentration built up due to

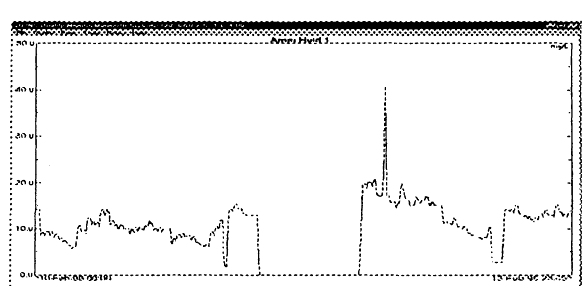

Figure 1. NH_4-N (mg/L) Time Series In The Crude Sewage - A Presentation Of Raw Time Series.

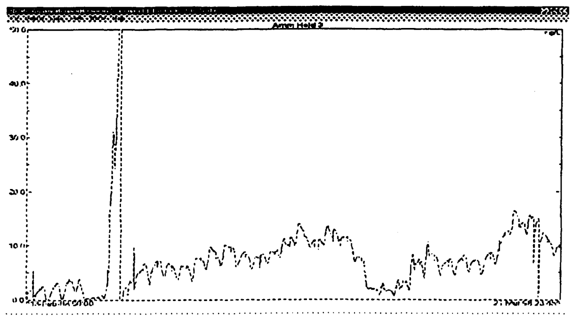

Figure 2. NH_4-N (mg/L) Time Series In The Inner Channel Around The Time The Water Level Was Adjusted.

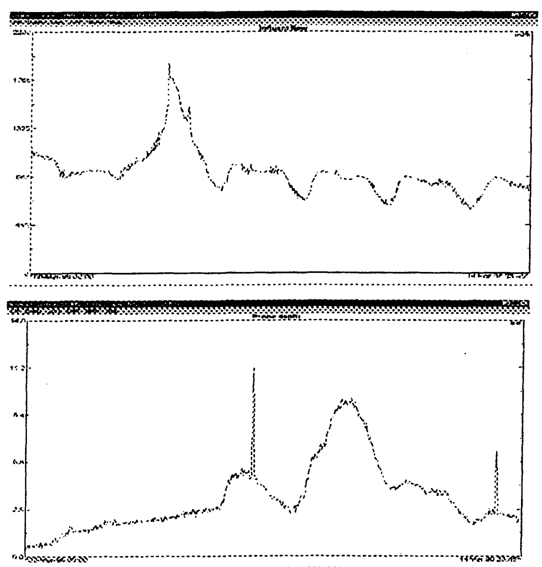

Figure 3. Influent Flow And Sludge Blanket Level During A Rain Event.

the deficit of DO as a result of the reduced aeration input. Once the loss of nitrification was detected, the water level was raised back on both March 12 and March 18. Figure 2 shows the ammonium-N concentration in the inner channel of aeration tank No. 2 during that time span. The surge in the curve was when the ammonium-N monitor was suspended and the TOC monitor was being serviced.

Process Control

During heavy rain events, the high flow rate to the plant leads to high concentrations of suspended solids in the secondary clarifier effluent. Figure 3 shows the wastewater flow and the sludge blanket level in one of the secondary clarifiers during a major rain event.

The sludge level increased on this occasion towards the surface of the secondary clarifier, causing heavy sludge loss with the secondary clarifier outflow. In such events the plant adopted alternative strategies to preserve the activated sludge. One option was that the influent flow was directed to the inner channel of the aeration tank, bypassing the first two. The returned activated sludge, however, was stored in the outer channel until the inflow dropped to a normal level.

PROCESS MODELING

Current research is focusing on developing and evaluating a dynamic model of the activated sludge process, based on the format of the IAWQ model No. 2 (Henze et al., 1995). Preliminary results are encouraging, as shown in Figure 4, for a small portion of the retrieved data set.

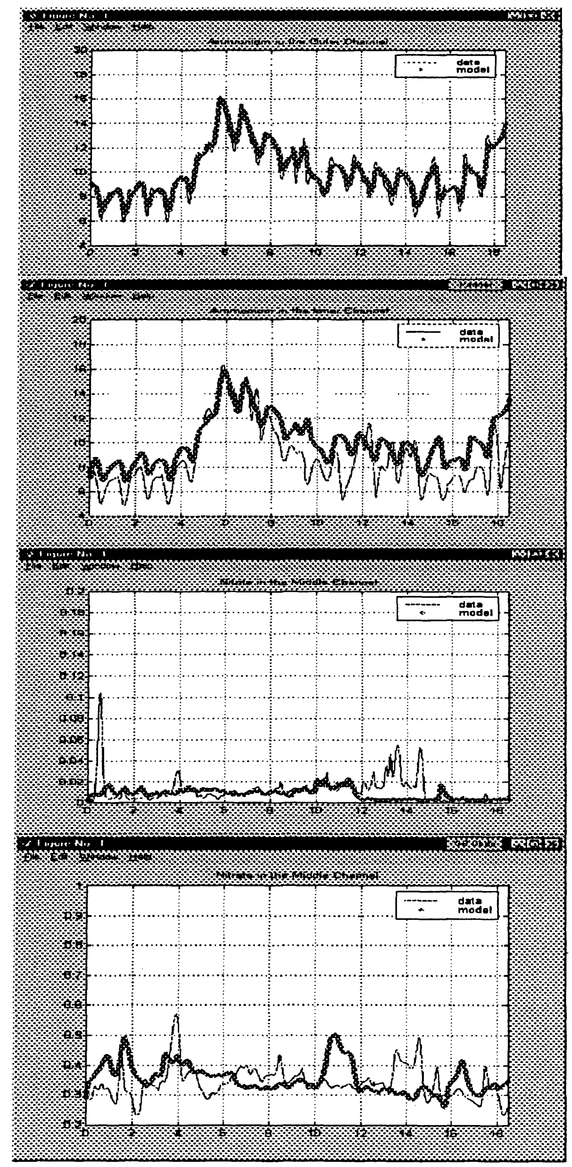

Figure 4. Preliminary Model Results for Nitrification and Denitrification Process From March 12 to March 31 (The Unit of the Time Scale Is D).

CONCLUSIONS

Within the past 18 months the University of Georgia's Environmental Process Control Laboratory has demonstrated unequivocally its considerable potential for comprehensive, real-time monitoring of, inter alia, biological wastewater treatment systems. It has also enabled more rigorous studies of process modeling to be undertaken and these, together with applications of advanced signal processing algorithms, will be the focus of our studies in the immediate future.

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